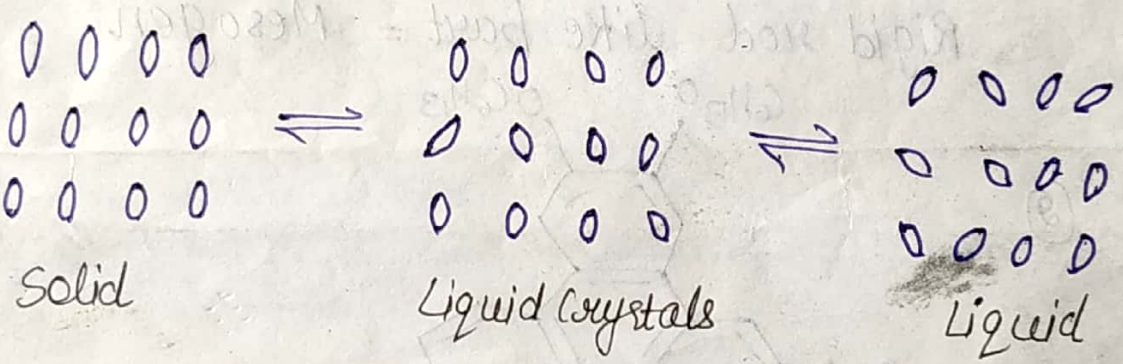
Liquid Crystals

Liquid crystal → Liquid crystal is a state of matter whose properties are between those of conventional liquids and those of solid crystals.

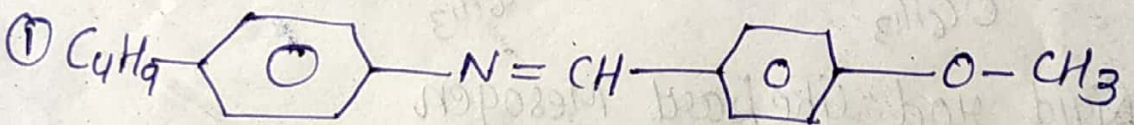
For example, a liquid crystal may flow like a liquid, but its molecules may be arranged or oriented in crystal like way.

Liquid crystals exhibit intermediate thermodynamic phases between crystalline solid and simple liquid state.

These phases are called liquid crystalline phases or mesomorphic phases.



eg→ Liquid Crystalline Molecules

① 

Methoxybenzilidene Butylaniline (MBBA)

② paraffins → flammmable waxy substance obtained from wood, coal used in candles, ~~cosmetics~~ cosmetics

③ cellulose derrivatives → use in pharmaceutricals

④ surfactants → surface active agents

substances such as detergents that when added to liquid, reduces its surface tension, there by increasing its spreading and wetting properties.

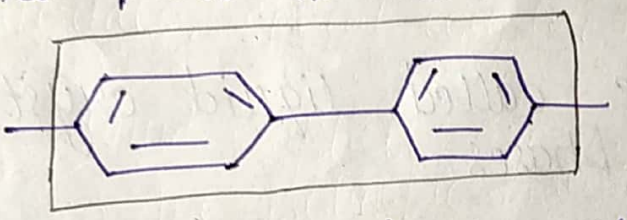
Mesogen

Mesogen is the fundamental unit of liquid crystal that induces structural order in the crystals.

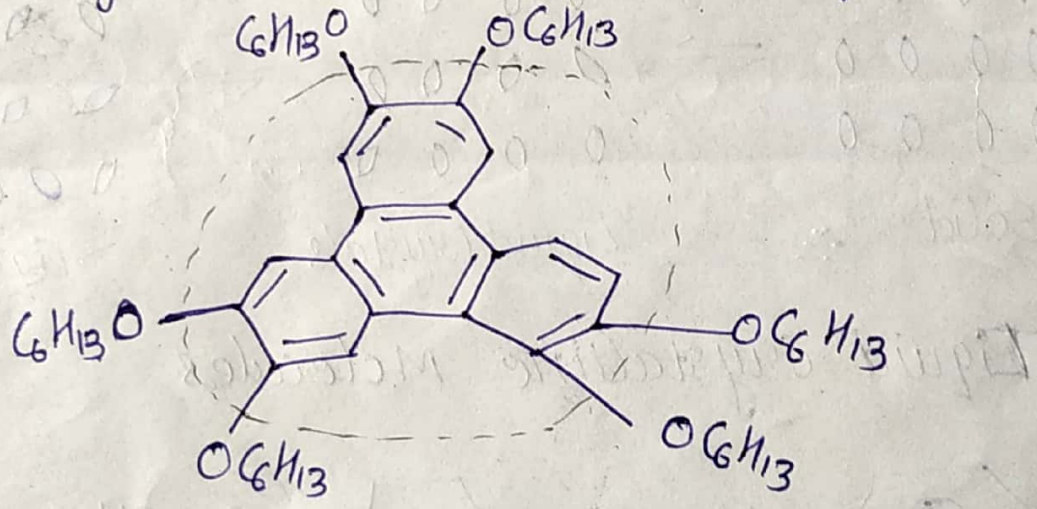
Typically, a liquid crystalline molecule consists of a rigid moiety and one or more flexible parts.

The rigid part aligns the molecule in one direction, whereas the flexible parts induces fluidity in the liquid crystal.

This rigid part is referred to as mesogen.

e.g. ① 

Rigid rod like part = Mesogen

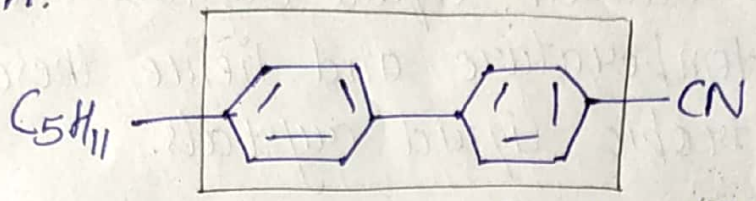
② 

Rigid rod like part Mesogen

Calamitic Liquid crystals

In a calamitic liquid crystals, mesogen is a rod like structure composed of two or more aromatic and aliphatic rings connected in one direction.

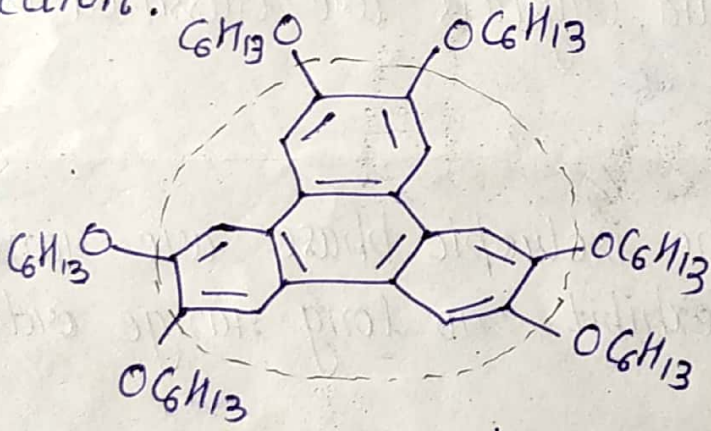
e.g



Rigid rod like part → Mesogen

Discotic Liquid crystals

In a discotic liquid crystals, the flat shaped aromatic core that makes molecules stack in one direction.



Rigid disc like part → Mesogen

Classification of Liquid crystals

Liquid crystals can be classified into (i) thermotropic and (ii) lyotropic liquid crystals

(i) Thermotropic liquid crystals

The transitions between liquid crystals are given by change in temperature and hence these are called thermotropic liquid crystals.

~~(ii) lyotropic liquid crystals~~

Thermotropic liquid crystals are mostly used for technical applications such as display materials, information storage materials, optical coupler etc. (Optical coupler → are photonic devices enable of dividing an optical signal from one port to other ports)

Thermotropic liquid crystals are classified as:

→ Thermotropic liquid crystals are classified as:

or

→ Classification of liquid crystals on the basis of temperature:

→ Polymorphism in Thermotropic Liquid Crystals

Polymorphosim means many forms

(i) Nematic Phase

- Nematic Phase is the simplest form of liquid crystals.
- It is characterised by high degree of long range orientation order of molecule.
- In this phase crystal molecules have no arranged positions and are free to move in any way they like.
- They donot have any specific order, molecules point in same direction.
- In Nematic phases molecules can be easily aligned by external magnetic or electric field.
- Nematics are polarisable rod like molecules of 20 Å in length (Angstroms)

Nematic phase

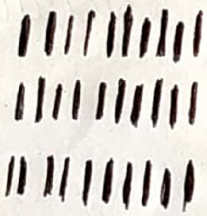
Uses

- The use of nematic liquid crystals in telescope lenses is common because it allows for clear image when researcher are faced with atmospheric turbulance.
- Digital watch which was used in 80's functioned with nematic liquid crystals.
- Twisted nematic has optical properties which makes them extremly useful in liquid crystal display (LCD).

(ii) Smectic Phase

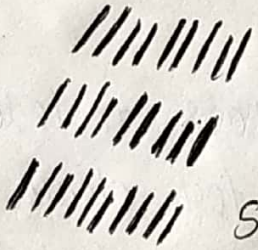
- In Smectic phase molecules line up in the layers. Keeping the same orientation and pointing in the same direction as the molecules in nematic liquid crystals.
- While these layers move freely, movement within the layers is restricted. Therefore it forms a slightly more solid substance.
- The smectic phases are found at lower temperatures than nematic phases.
- Smectics phases can be classified into several categories. The two out of these are:

Smectic A phase → In smectic A phase, molecules are are aligned perpendicular to the layer planes.



Smectic A phase

Smectic C phase → In Smectic C phase, alignment of molecules is at some angle to the normal.



Smectic C phase

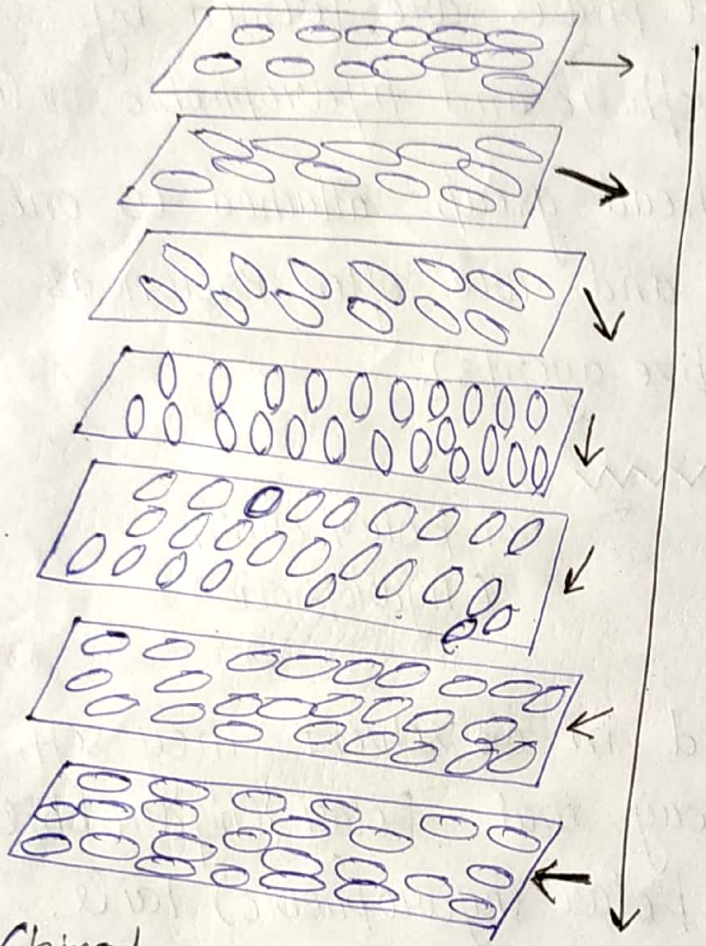
- The smectic phase, like nematic, exhibits long range orientational order of molecules.

Use

- Smectic liquid crystals have been found to have fast electro-optical response times and are therefore used in conjuction with nematic liquid crystals in making liquid crystal display (LCD) screens.

(iii) Chiral Nematic phase:

- These are also known as Cholesteric phase.
- In this phase, molecules twist slightly from one layer to the next, resulting in a spiral formation.
- And This prevents a substance from being crystalline or solid.



Chiral nematic liquid
or
Cholesteric phase

Use →

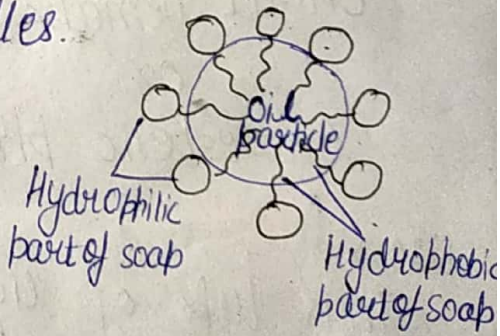
This type of liquid crystals also has characteristic of changing colour when exposed to different temperatures. This is why cholesteric liquid crystals are used in common household items such as thermometers and mood rings.

Lyotropic Liquid Crystals

Lyotropic liquid crystals → The phase transitions may also depend on concentration of mesogen in solvent, and these liquid crystals are called lyotropic.

- Lyotropic liquid crystal phases are formed by amphiphilic (both hydrophilic and hydrophobic) molecules.
- These consist of polar head group attached to one or more non polar chains and are often known as surfactants (surface active agents).

- When these are dissolved in an solvent they self assemble in such a way that polar (hydrophilic) head protect the non polar (hydrophobic) tails. These structures are known as micelles.



- Lyotropic liquid crystalline phases are abundant in living systems, study of which is referred to as polymorphism.

Lyotropic Liquid crystals are important for biological systems:

- Biological membranes and cell membranes are a form of liquid crystal.
- Concentrated protein solution that is extruded by spider to generate silk is liquid crystal phase.

Applications of Liquid crystals

The most remarkable features of liquid crystals with respect to applications are due to their anisotropic optical properties.

The most successful application of liquid crystal displays are well known in wrist watches, pocket calculators or flat screens of laptop computer which take advantage of electro-optical effects.

① Liquid Crystal Displays

- The most common application of liquid crystal technology is liquid crystal displays (LCDs).
- This field has grown into a multi-billion dollar industry and many significant scientific and engineering discoveries have been made.
- Liquid crystals rely on optical properties of certain liquid crystalline substances in the presence or absence of an electric field.
- A liquid crystal display (LCD) is a thin display device made up of any number of colours or monochrome pixels arrayed in front of a light source or reflector.

- LCD (liquid crystal display) is the technology used for displays in notebook and smaller computers.
- Like LED (light emitting diode) and gas plasma technologies, LCDs allow displays to be much thinner than cathode ray tube (CRT) technology.
- LCDs consume much less power than LED and gas display because they work on principle of blocking light rathan than emitting it.

(2) Liquid Crystal Thermometers

- Chiral nematic (cholesteric) liquid crystals has characteristic of changing colour when exposed to different temperatures. This is why cholesteric liquid crystals are used in thermometers and mood rings.
- More important and practical applications have been developed in medicine and electronics.
- Special liquid crystal devices can be attached to the skin to show a map of temperatures. This is useful because physical problems, such as tumours have a different temperature than surrounding tissue.
- Liquid crystal temperature sensors can also be used to find bad connections on a circuit board by detecting the characteristic higher temperature.

③ Optical imaging

- An application of liquid crystals is being explored in optical imaging and recording.
- In this technology, a liquid crystal cell is placed between two layers of photo conductors.
- Light is applied to the photo conductor, which increases the material's conductivity. This causes an electric field to develop in liquid crystal corresponding to the intensity of light.
- The electric pattern can be transmitted by an electrode, which enables the image to be recorded.
- This is one of the most promising areas of liquid crystal research.

④ Other liquid crystals applications.

Liquid crystals have multible uses.

(a) This technique is also used for visualisation of radiofrequency waves in waveguides

(b) They are used in medical applications for example where in transient pressure transmitted by a walking foot on ground, is measured.

(c) Low molar mass liquid crystals have applications in erasable optical disks, full colour electronic slides for computer aided drawing (CAD) and light modulators for colour electronic imaging.

(d) Liquid crystal technology has major effect on many areas of science and technology engineering, as well as device technology.

5 Liquid crystal lenses:

Liquid crystal lenses can change their focal length dynamically in response to applied electric field. These lenses find applications in cameras, microscopy and other optical systems.

6 Liquid crystal sensors:

Liquid crystals can be employed as sensors to detect various environmental parameters like temperature, pressure and chemical concentrations.

7 Liquid crystal windows:

Smart windows and privacy glass use liquid crystals to control light transmission, allowing them to change from clear to opaq4 with application of electric field.

8 Optical devices:

Liquid crystals are used in the range of optical devices, including polarizers. These can be employed to control the polarization of light or change in direction of light beam.

Industrially important material used as liquid crystals:

1. Nematic liquid crystals: These are commonly used in liquid crystal displays (LCDs), such as those found in computer monitors, television screens, and mobile phones.

2. Cholesteric liquid crystals: Cholesteric or chiral nematic liquid crystals have helical structure. These are used in applications like thermochromic materials (color-changing materials sensitive to temperature) and security inks.

3. Discotic liquid crystals: Discotic liquid crystals consist of disk-shaped molecules. These find applications in organic electronic devices, such as organic photovoltaics and organic light emitting diode (OLEDs).

4. Polymer-Dispersed Liquid crystals: These are used in smart windows and privacy glass.

5. Ferroelectric liquid crystals: These materials are used in non-linear optical devices, memory displays and other advanced applications.

6. Guest-Host liquid crystals: These are utilized in optical filters and displays.